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(continued on next page)

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US 5864416 B
US 5088107 B
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US 4051363 B

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UK CL (Edition W) **H4B**
INT CL^7 **H04B**
Other: **WPI, EPODOC, JAPIO.**

(54) Abstract Title: **Fibre optic receiver with a post amplifier comprising wide and narrow bandwidth paths**

(57) A fiber optic receiver 10 is described. The receiver 10 includes a substrate 62, a receiver optical sub-assembly (ROSA) 60 mounted on the substrate 62 and comprising a fiber optic connector 32 for coupling to a mating connector 30 of a fiber optic cable 18. The ROSA 60 also includes an opto-electronic transducer 12 configured to generate an electrical data signal in response to a received optical data signal. A pre-amplifier circuit 14 is coupled to the opto-electronic transducer 12 and linearly amplifiers the generated electrical data signal. An adjustable bandwidth post-amplifier circuit 16 including a wide bandwidth signal path 100 and a narrow bandwidth signal path 102 is coupled to an output of the preamplifier circuit 14.

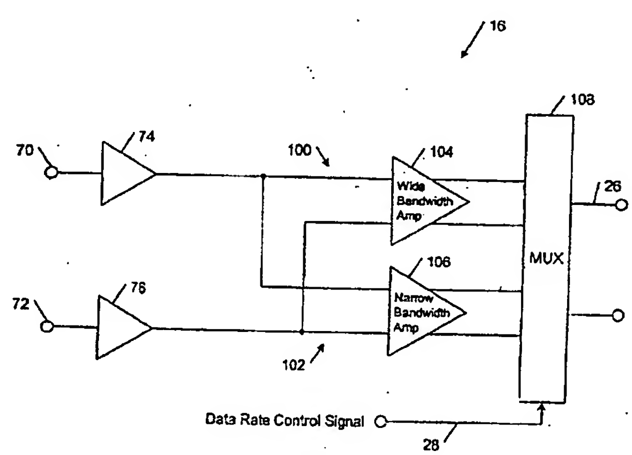

FIG. 4

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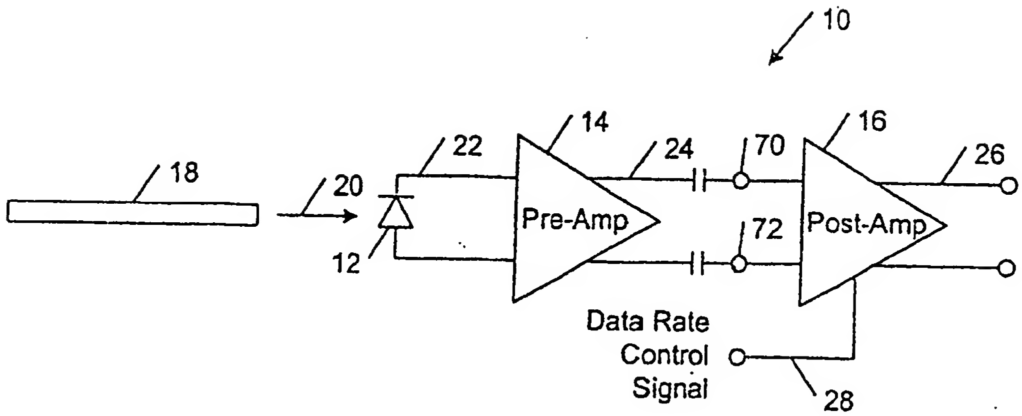
10
18
20
12
22
14
24
70
72
16
26
Pre-Amp
Post-Amp
Data Rate
Control
Signal
28

FIG. 1

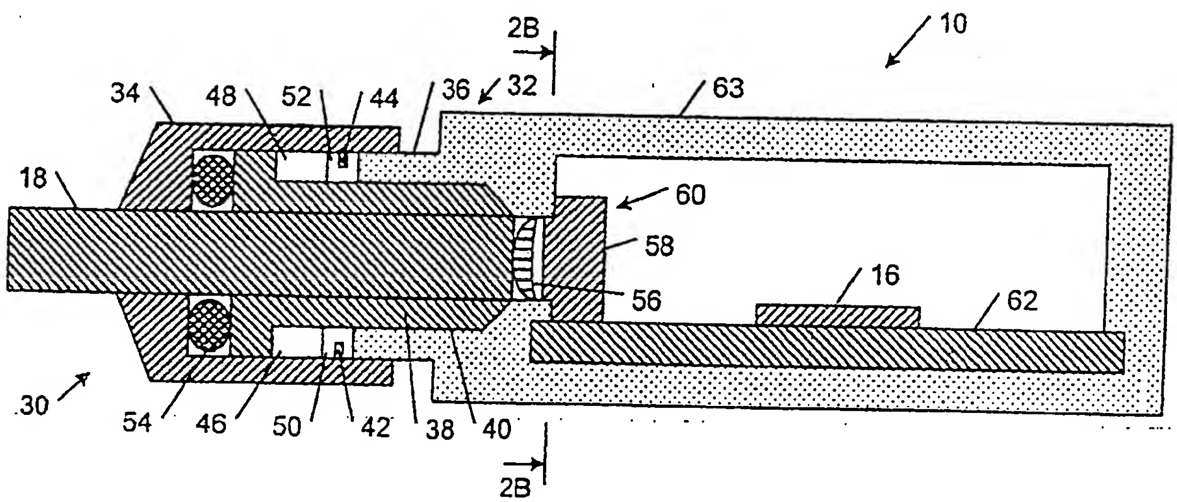
2B
10
34
48
52
44
36
32
63
18
60
58
16
56
62
30
54
46
50
42
38
40
2B

FIG. 2A

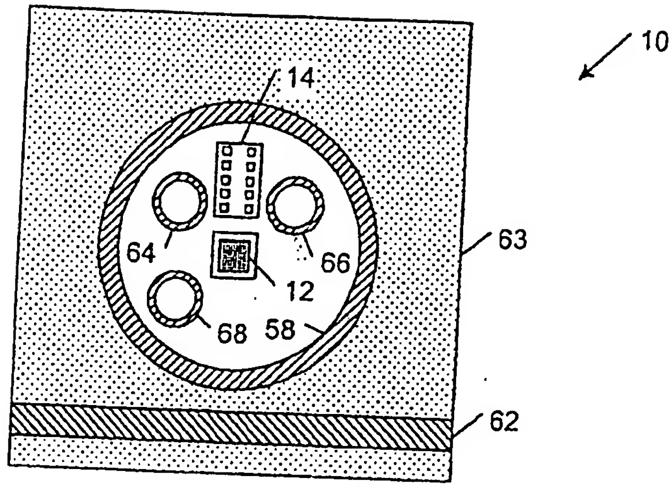
10
14
63
64
66
12
68
58
62

FIG. 2B

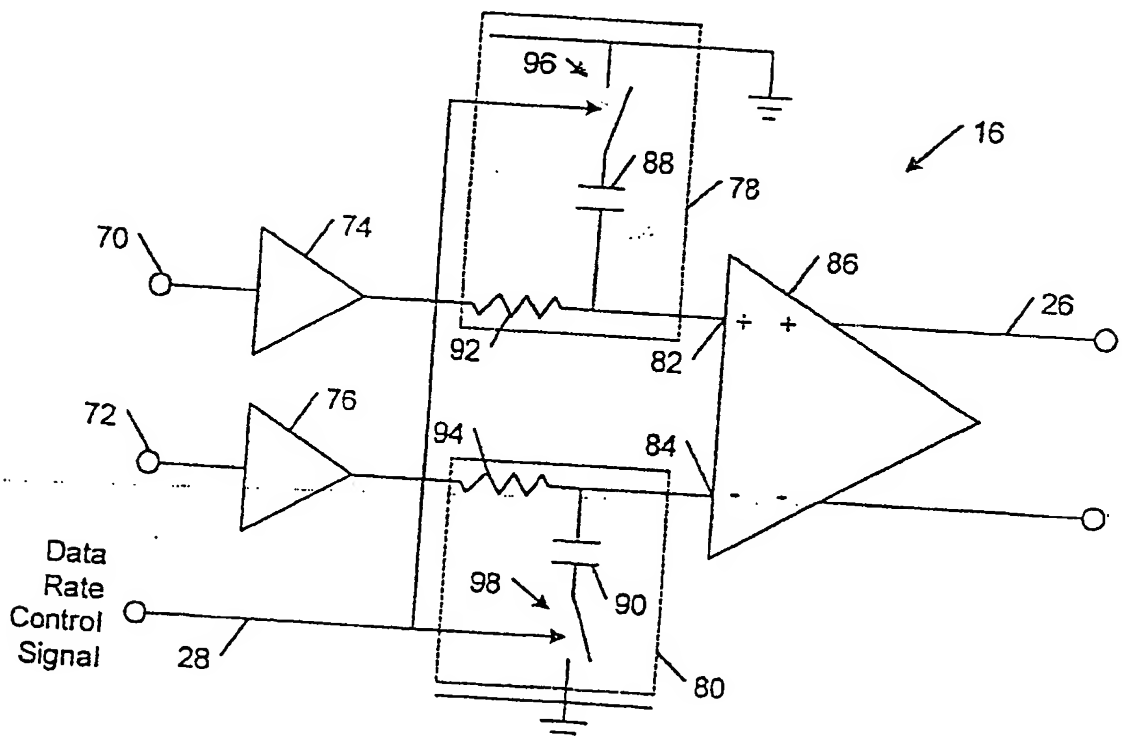
96
88
78
16
70
74
86
26
92
82
72
76
94
84
Data
Rate
Control
Signal
28
98
90
80

FIG. 3

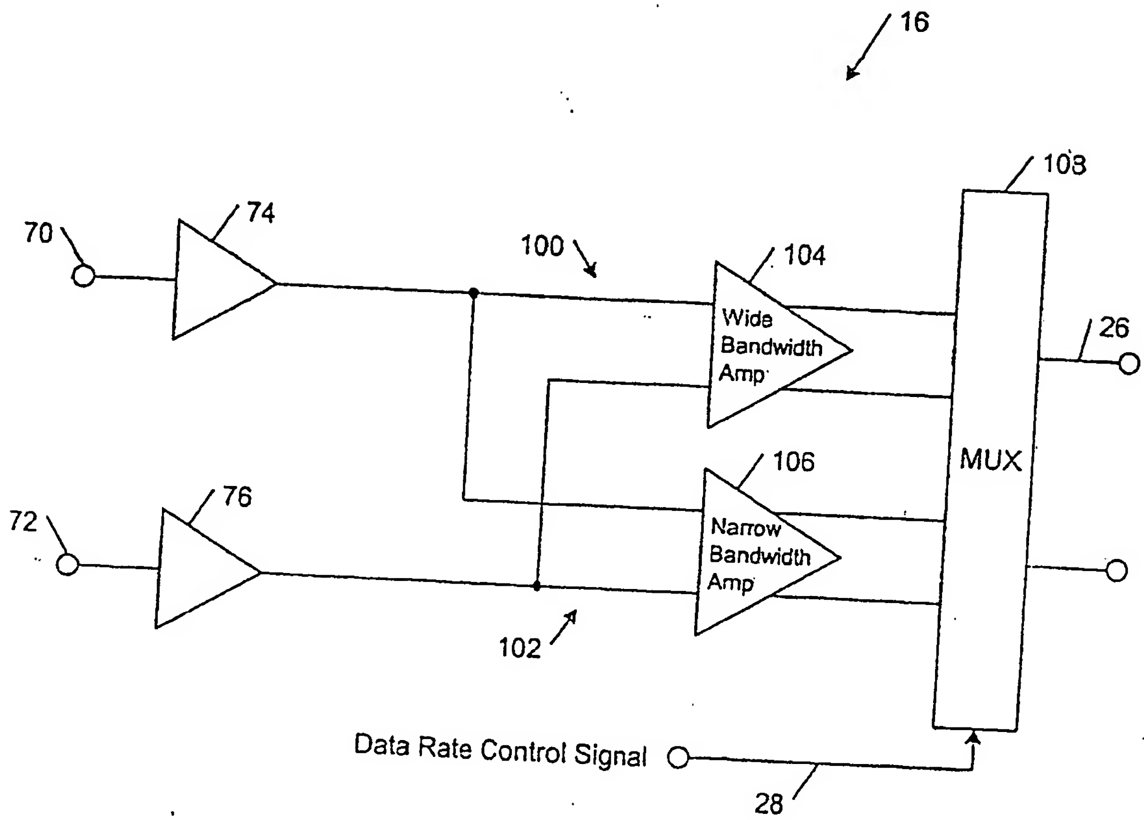
16
108
74
70
100
104
Wide
Bandwidth
Amp
26
106
MUX
76
72
Narrow
Bandwidth
Amp
102
Data Rate Control Signal
28

FIG. 4

FIBER OPTIC RECEIVER

This invention relates to a fiber optic receiver and in particular to fiber optic receivers and wideband receiver-amplifiers subject to relatively tight packaging constraints.

Many advanced communication systems transmit information through a plurality of parallel optical communication channels. The optical communication channels may be defined by a fiber optic ribbon interconnect (or fiber optic cable) formed from a bundle of glass or plastic fibers, each of which is capable of transmitting data independently of the other fibers. Relative to metal wire interconnects, optical fibers have a much greater bandwidth, they are less susceptible to interference, and they are much thinner and lighter. Because of these advantageous physical and data transmission properties, efforts have been made to integrate fiber optics into computer system designs. For example, in a local area network, fiber optics may be used to connect a plurality of local computers to centralized equipment, such as servers and printers. In this arrangement, each local computer has an optical transceiver for transmitting and receiving optical information. The optical transceiver may be mounted on a substrate that supports one or more integrated circuits. Typically, each computer includes several substrates that are plugged into the sockets of a common backplane. The backplane may be active (i.e., it includes logic circuitry for performing computing functions) or it may be passive (i.e., it does not contain any logic circuitry). An external network fiber optic cable may be connected to the optical transceiver through a fiber optic connector that is coupled to the backplane.

Fiber optic transceivers typically include transmitter and receiver components. The transmitter component typically includes a laser, a lens assembly, and a circuit for driving the laser. The fiber optic receiver component typically includes a photodiode and a high gain receiver amplifier, which may be operable to perform one or more signal processing functions (e.g., automatic gain control, background current canceling, filtering or demodulation). For one-directional data transfer, a transmitter component is required at the originating end and a receiver component is required at the answering

end. For bi-directional communication, a receiver component and a transmitter component are required at both the originating end and the answering end. In some cases, the transmitter circuitry and the receiver circuitry are implemented in a single transceiver integrated circuit (IC). The transceiver IC, photodiode and laser, along with the lenses for the photodiode and the laser are contained within a package that has a size that is sufficiently small to fit within a fiber optic communication device.

According to an aspect of the present invention, there is provided a fiber optic receiver according to claim 1.

The post-amplifier circuit preferably further comprises a multiplexer configured to selectively present for output electrical data signals transmitted over either the wide bandwidth signal path or the narrow bandwidth signal path in response to a received data rate control signal. The wide bandwidth signal path preferably comprises an amplifier with a relatively wide

bandwidth response and the narrow bandwidth signal path preferably comprises an amplifier with a relatively narrow bandwidth response.

The post-amplifier may include an input gain buffer coupled to the output of the preamplifier circuit. The pre-amplifier circuit preferably is configured to linearly amplify an electrical data signal generated by the opto-electronic transducer over a specified range of optical data signal power. The ROSA may include a header module that is mounted on the substrate and is configured to house the opto-electronic transducer and the preamplifier. The opto-electronic transducer preferably includes a photodiode.

Among the advantages of the invention are the following.

The invention provides a fiber optic receiver that accommodates multiple data rates while conforming to existing receiver optical sub-assembly (ROSA) size and pin count constraints. In addition, the inventive placement of the adjustable bandwidth amplifier outside the ROSA enables the analog electrical data signals generated by the opto-electronic transducer to be amplified and shaped properly for data recovery, while allowing the receiver to be housed within a package sized to fit within fiber optic communication devices with significant size constraints.

Other features and advantages of the invention will become apparent from the following description of a number of preferred embodiments of the present invention with reference to the drawings in which:

FIG. 1 is a diagrammatic view of a fiber optic receiver, which includes an opto-electronic transducer, a preamplifier circuit and a post-amplifier circuit, and a fiber optic cable carrying an optical data signal to the fiber optic receiver.

FIG. 2A is a diagrammatic cross-sectional side view of a fiber optic cable coupled by a pair of mating connectors to a receiver optical sub-assembly (ROSA) of the fiber optic receiver of FIG. 1.

FIG. 2B is a diagrammatic cross-sectional end view of a header module of the ROSA of FIG. 2A taken along the line 2B-2B.

FIG. 3 is a circuit diagram of the post-amplifier circuit of FIG. 1.

FIG. 4 is a circuit diagram of a post-amplifier circuit.

In the following description, like reference numbers are used to identify like elements. Furthermore, the drawings are intended to illustrate major features of exemplary embodiments in a diagrammatic manner. The drawings are not intended to depict every feature of actual embodiments or relative dimensions of the depicted elements, and are not drawn to scale.

Referring to FIG. 1, a fiber optic receiver 10 includes an opto-electronic transducer 12 (e.g., a p-i-n photodiode), a preamplifier circuit 14, and an adjustable bandwidth post-amplifier circuit 16. In operation, a fiber optic cable 18 carries an optical data signal 20 to opto-electronic transducer 12. In response to optical data signal 20, opto-electronic transducer 12 generates an electrical data signal 22, which is amplified by preamplifier circuit 14. Preamplifier circuit 14 is configured to linearly amplify electrical data signal 22 over a prescribed range of optical power for optical data signal 20. The resulting pre-amplified electrical data signal 24 is further amplified by post-amplifier circuit 16, which amplifies and shapes electrical data signal 24 so that data embedded in output signal 26 may be extracted by a conventional clock and data recovery circuit.

As explained in detail below, post-amplifier circuit has an adjustable bandwidth response that may be set by a data rate control signal 28 to optimize the performance of fiber optic receiver 10 for different data rates. For example, in one embodiment, when the data rate of the received optical data signal 20 is high, the cutoff frequency of post-amplifier 16 is set high (e.g., about 1.5 GHz to about 2.5 GHz), whereas when the data rate is low, the cutoff frequency of post-amplifier circuit 16 is set low (e.g., about 0.5 GHz to about 1.5 GHz). The data rate of optical data signal 20 may be known *a priori* or may be extracted by a phase-locked loop or other techniques in the clock and data recovery circuit.

As shown in FIG. 2A, fiber optic cable 18 includes a cable connector 30 that couples to a mating receiver connector 32 of fiber optic receiver 10. Cable connector 30 includes a socket 34 that is configured to slide over a protruding lip 36 of receiver connector 32. An annular sleeve 38 is disposed about the distal end of fiber optic cable 18 and is configured to slide within a channel 40 defined within receiver connector 32. Socket 34 has a pair of pins 42, 44 that are slidable within

vertical slots 46, 48 of lip 36. Socket 34 may be slid over lip 36, with pins 42, 44 aligned with slots 46, 48, until pins 42, 44 reach the ends of slots 46, 48. Socket 34 then may be rotated to seat pins 42, 44 in end extensions 50, 52 of slots 46, 48. The process of seating pins 42, 44 within end extensions 50, 52 compresses a biasing mechanism 54 (e.g., a rubber o-ring) that urges socket 34 against receiver connector 32, effectively locking cable connector 30 to receiver connector 32. When properly seated within channel 40, the one or more fibers of fiber optic cable 18 are aligned with a lens assembly 56, which focuses optical data signals 20 onto opto-electronic transducer 12.

Referring to FIG. 2B, opto-electronic transducer 12 and preamplifier circuit 14 are housed within a header module 58 of a receiver optical sub-assembly (ROSA) 60, which is mounted on a substrate 62 (e.g., a printed circuit board or other support for passive and active components) of fiber optic receiver 10. ROSA 60 and substrate 62 are contained within a receiver package 63. Opto-electronic transducer 12 is mounted centrally within ROSA 60 to receive optical data signals carried by fiber optic cable 18 that are focused by lens 56. ROSA 60 also includes a plurality of insulated posts 64, 66, 68, which define channels through which electrical connectors extend to couple substrate 62 to opto-electronic transducer 12 and preamplifier circuit 14. Because the bandwidth limiting circuitry needed to amplify and shape the analog signals received from opto-electronic transducer 12 is placed within post-amplifier circuit 16, the space within ROSA 60 that is needed to contain opto-electronic transducer 12 and preamplifier circuit 14 may be reduced and, as a result, receiver package 63 may be constructed with a relatively small size.

Referring to FIG. 3, post-amplifier circuit 16 includes a positive input 70 and a negative input 72, each of which is coupled to a respective input gain buffer 74, 76. The outputs of gain buffers 74, 76 are coupled to low-pass filters 78, 80 and the inputs 82, 84 of a high gain amplifier 86, respectively. Low-pass filters 78, 80 each includes a capacitor 88, 90 and a resistor 92, 94 coupled in series. Low-pass filters 78, 80 also include respective switches 96, 98, which are configured to selectively set the bandwidth response of post-amplifier circuit 16 in accordance with the value of data rate control signal 28. In operation, when the data rate of the received optical data signal 20 is high, data rate control signal 28 is low, which opens switches

96, 98 to disconnect capacitors 88, 90 from the signal paths through post-amplifier circuit 16. As a result, the cutoff frequency of post-amplifier 16 is set high (e.g., about 1.5 GHz to about 2.5 GHz). When the data rate is low, data rate control signal 28 is set high, which closes switches 96, 98 to connect capacitors 88, 90 to the signal paths through post-amplifier circuit 16. As a result, the cutoff frequency of post-amplifier circuit 16 is set low (e.g., about 0.5 GHz to about 1.5 GHz).

Referring to FIG. 4, in an embodiment, post-amplifier circuit 16 includes a wide bandwidth signal path 100 and a narrow bandwidth signal path 102. Wide bandwidth signal path 100 includes an amplifier 104 that is characterized by a relatively high cutoff frequency (e.g., about 1.5 GHz to about 2.5 GHz) and narrow bandwidth signal path 102 includes an amplifier 106 that is characterized by a relatively low cutoff frequency (e.g., about 0.5 GHz to about 1.5 GHz). Post-amplifier circuit 16 also includes a multiplexer 108, which is configured to selectively present for output electrical data signals carried by one of wide bandwidth signal path 100 and narrow bandwidth signal path 102 in response to the value of data rate control signal 28. In particular, when the data rate of the received optical data signal 20 is high, data rate control signal 28 is high. As a result, multiplexer 108 presents for output the electrical data signals carried by wide bandwidth signal path 100. When the data rate of the received optical data signal 20 is low, data rate control signal 28 is low. As a result multiplexer 108 presents for output the electrical data signals carried by narrow bandwidth signal path 102.

Receiver 10 may be housed within a standalone receiver package or may be housed together with a transmitter component in a transceiver package.

Other embodiments are within the scope of the claims.

For example, although the above-embodiments are described in connection with a post-amplifier circuit with two different bandwidth responses, other embodiments may include post-amplifiers with more than two different bandwidth responses. Furthermore, other post-amplifiers may have a continuously variable bandwidth response, rather than a discrete variation in bandwidth response. The bandwidth response of the post-amplifier circuit also may be adjusted in different ways. For example, the bandwidth response may be adjusted by varying the bias conditions of a variable transconductance transistor in the post-amplifier circuit. Alternatively, the

bandwidth response may be adjusted by varying the bias voltage applied to a varactor (voltage-variable capacitor) in the post-amplifier circuit. In addition, instead of varying capacitance values as in the above-described embodiments, the resistance values in the low-pass filters coupled to the signal paths through the post-amplifier circuit may be varied. The bandwidth response alternatively may be adjusted by varying the gain of an amplifier within the post-amplifier circuit.

Other embodiments may use fiber optic connectors that are different from the bayonet-type connectors 30, 32 to couple fiber optic cable 18 to receiver 10.

CLAIMS

1. A fiber optic receiver (10), comprising:

a substrate (62);

a receiver optical sub-assembly (ROSA) (60) mounted on the substrate (62) and comprising a fiber optic connector (32) for coupling to mating connector (30) of a fiber optic cable (18);

an opto-electronic transducer (12) incorporated within the ROSA (60) and configured to generate an electrical data signal in response to a received optical data signal;

a preamplifier circuit (14) coupled to the opto-electronic transducer (12), and operable to linearly amplify an electrical data signal generated by the opto-electronic transducer (12); and

an adjustable bandwidth post-amplifier circuit (16) coupled to an output of the preamplifier circuit (14) the post-amplifier circuit (16) comprising a wide bandwidth signal path (100) and a narrow bandwidth signal path (102).

2. A fiber optic receiver as claimed in claim 1, wherein the post-amplifier circuit (16) further comprises a multiplexer (108) configured to selectively present for output electrical data signals transmitted over one of the wide bandwidth signal path (100) and the narrow bandwidth signal path (102) in response to a received data rate control signal (28).

3. A fiber optic receiver as claimed in claim 1 or 2, wherein the wide bandwidth signal path (100) comprises an amplifier (104) with a relatively wide bandwidth response and the narrow bandwidth signal path (102) comprises an amplifier (106) with a relatively narrow bandwidth response.

4. A fiber optic receiver as claimed in any preceding claim, wherein the post-amplifier (16) comprises an input gain buffer (74, 76) coupled to the output of the preamplifier circuit (14).

5. A fiber optic receiver as claimed in any preceding claim, wherein the pre-amplifier circuit (14) is configured to linearly amplify an electrical data signal generated by the opto-electronic transducer (12) over a specified range of optical data signal power.

6. A fiber optic receiver as claimed in any preceding claim, wherein the ROSA (60) comprises a header module (58) mounted on the substrate (62) and configured to house the opto-electronic transducer (12) and the preamplifier (14).

7. A fiber optic receiver as claimed in any preceding claim, wherein the opto-electronic transducer (12) comprises a photodiode.

8. A fiber optic receiver substantially as hereinbefore described with reference to and as illustrated in Figure 4 of the accompanying drawings.

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Application No: GB0418142.6 **Examiner:** Dr Stephen Brown

Claims searched: 1-8 **Date of search:** 24 September 2004

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	US5864416 B (Harris Corp) See especially the abstract and figure 1.
A	-	US5088107 B (Crystal Semiconductor) See especially the abstract and figures 1 & 4.
A	-	US5311353 B (Analog Modules) See especially the abstract and figure 2.
A	-	US4051363 B (US Navy) See especially the abstract and figure 3.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Field of Search:

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Worldwide search of patent documents classified in the following areas of the IPC^{07}

H04B

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, JAPIO.